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How many extant pinniped species remain to be described?

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Large extant marine vertebrates continue to be discovered and described: during the late twentieth and early twenty-first century, several cetaceans and chondrichthyans exceeding three metres in total length have been described, including the megamouth shark, Omura's whale, Bandolero (or Peruvian or Lesser) beaked whale, and Perrin's beaked whale. Statistical methods have been employed by several workers in an effort to estimate the number of such species that remain to be described, and results indicate that between 10 and c. 50 such species remain. Here, we examine the description record of the pinnipeds using non-linear and logistic regression models in an effort to determine how many members of this group might remain undescribed. Regression based on a Michaelis–Menten function suggests that as many as 15 such species remain, whilst logistic regression suggests a far lower number (closer to 0). We combine these approaches with an evaluation of cryptozoological data, as ethnozoological evidence suggests the existence of several large-bodied marine vertebrates that have been interpreted by some authors as unusual pinnipeds. These include the so called 'long-necked sea-serpent', 'merhorse' and 'tizhurek'. Because cryptozoological data are mostly discussed in the 'grey literature', appraisals of these cryptids have never appeared in the mainstream literature, perpetuating a cycle whereby these putative animals remain unevaluated.

Keywords: pinnipeds; description record; non-linear regression; logistic regression; cryptozoology; ethnozoology

Introduction

Pinnipeds are amphibious carnivorans, represented in the extant fauna by c. 36 species in 18–21 genera (depending on the favoured taxonomy). These range worldwide, occurring in tropical, temperate and polar seas, in the pelagic realm, in coastal waters, and even in land-locked lakes such as Lake Baikal, Lake Iliamna in Alaska, the Lacs des Loups Marins of northern Quebec, and Lake Saimaa and Lake Ladoga in Fennoscandia. Crown-group pinnipeds have a fossil record extending back to the Upper Oligocene (Koretsky and Sanders 2002): stem-pinnipeds (united with the crown-group in the more inclusive clade Pinnipedimorpha) are also known from the Upper Oligocene (Berta 1991; Deméré et al. 2003) but are hypothesised to have first appeared in the Early Oligocene. All extant pinnipeds belong to one of three clades: Odobenidae (the extant walrus *Odobenus rosmarus* and its fossil relatives), Otariidae (the c. 15 species and 7 genera of sea lions and fur seals), and Phocidae (the c. 20 species and 10–13 genera of 'true' seals). The origins, interrelations and evolutionary history of these three groups have been the subject of much controversy and a voluminous literature (Bininda-Emonds and Russell 1996; Berta and Sumich 1999; Deméré et al. 2003).

Whereas it was, until recently, generally thought that the extant marine mammals of the world had all been described, recent discoveries have shown that the continuing description of new extant species should be expected. The Bandolero beaked whale (also known as the Peruvian or Lesser beaked whale) *Mesoplodon peruvianus*, known from specimens discovered between 1975 and 1989, was named as a new species in 1991 (Reyes et al. 1991); the Spade-toothed whale *M. traversii* was named in 1874 but later sunk into synonymy and was resurrected in 2002 when it was found to be synonymous with *M. bahamondi*, a supposedly new species named in 1995 (Reyes et al. 1995; van Helden et al. 2002); Perrin's beaked whale *M. perrini* is known from specimens discovered between 1975 and 1997 and was named as a new species in 2002 (Dalebout et al. 2002); and Omura's whale *Balaenoptera omurai* was first collected during the late 1970s and named as a new species in 2003 (Wada et al. 2003). Data indicate that we should expect the continuing discovery of large marine vertebrates: the Megamouth shark *Megachasma pelagios* was discovered in the Pacific in 1976 and named in 1983 (Taylor et al. 1983), the 2004 discovery of a morphologically unusual specimen in Sumatra has led to the suggestion that a second species

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might await recognition (White et al. 2004), and the Indonesian coelacanth *Latimeria menadoensis* was discovered in 1998 and named in 1999 (Pouyaud et al. 1999).

Perhaps because they rest or breed on land and are hence not fully divorced from the terrestrial realm, pinnipeds do not include species that have been scientifically described as recently as these cetaceans, sharks and coelacanths. Nevertheless eight species were described in the twentieth century: *Arctocephalus galapagoensis* Heller, 1904; *Monachus schauinslandi* Matschie, 1905, *Odobenus orientalis* (Dybowski, 1922), *A. doriferus* Wood Jones, 1925, *A. tasmanicus* Scott and Lord, 1926, *Zalophus wollebaeki* Sivertsen, 1953, *Phoca insularis* Belkin, 1964 and *P. kurilensis* McLaren, 1966. Of these eight, *A. doriferus* and *A. tasmanicus* are now regarded as subspecies of the Australian fur seal *A. pusillus* (named in 1775), *O. orientalis* is synonymous with *O. rosmarus*, and both *P. insularis* and *P. kurilensis* are now regarded as synonymous with *P. vitulina*. Both *A. galapagoensis* (the Galápagos fur seal) and *Z. wollebaeki* (the Galápagos sea lion) were known long prior to 1904 and 1953, respectively (Clark 1975; Bonner 1984), but only in those years were they argued to be worthy of distinct taxonomic status. *Z. wollebaeki* then proved controversial but was recently argued to be worthy of species status (Wolf et al. 2007). Wolf et al. (2007) also argued that the recently extinct Japanese sea lion *Z. japonicus* (named in 1866) was also distinct enough to warrant species status. *M. schauinslandi*, the Hawaiian monk seal, remains an uncontroversial twentieth century discovery. A complete list of extant pinniped species arranged in chronological order of description, along with their vernacular and scientific names and their respective authors, is given in Table 1.

In view of the data on recent, continuing discoveries of large marine animals, several workers have examined the discovery and description rates of such animals across time with the aim of determining the number of species that might still await description. By plotting species description rates over time to generate an asymptotic

Table 1. The description record of the pinnipeds.

Vernacular name	Scientific name	Author	Year described
Harbour seal	*Phoca vitulina*	Linnaeus	1758
Northern fur seal	*Callorhinus ursinus*	Linnaeus	1758
Southern elephant seal	*Mirounga leonina*	Linnaeus	1758
Walrus	*Odobenus rosmarus*	Linnaeus	1758
Australian fur seal	*Arctocephalus pusillus*	Schreber	1775
Ringed seal	*Pusa hispida*	Schreber	1775
Steller sea lion	*Eumetopias jubatus*	Schreber	1776
Bearded seal	*Erignathus barbatus*	Erxleben	1777
Harp seal	*Phoca groenlandica*	Erxleben	1777
Hooded seal	*Cystophora cristata*	Erxleben	1777
Mediterranean monk seal	*Monachus monachus*	Hermann	1779
Ribbon seal	*Histriophoca fasciata*	Zimmermann	1783
South American fur seal	*Arctocephalus australis*	Zimmermann	1783
Caspian seal	*Pusa caspica*	Gmelin	1788
Baikal seal or Nerpa	*Pusa sibirica*	Gmelin	1788
Gray seal	*Halichoerus grypus*	Fabricius	1791
South American or Southern sea lion	*Otaria flavescens*	Shaw	1800
Spotted seal	*Phoca largha*	Pallas	1811
Australian sea lion	*Neophoca cinerea*	Péron	1816
Leopard seal	*Hydrurga leptonyx*	Blainville	1820
Weddell seal	*Leptonychotes weddellii*	Lesson	1826
New Zealand fur seal	*Arctocephalus forsteri*	Lesson	1828
Californian fur seal	*Zalophus californianus*	Lesson	1828
Crabeater seal	*Lobodon carcinophaga*	Hombron and Jacquinot	1842
New Zealand sea lion	*Phocarctos hookeri*	Gray	1844
Ross seal	*Ommatophoca rossii*	Gray	1844
Caribbean or West Indian monk seal	*Monarchus tropicalis*	Gray	1850
Northern elephant seal	*Mirounga angustirostris*	Gill	1866
Japanese sea lion	*Zalophus japonicus*	Peters	1866
Juan Fernández fur seal	*Arctocephalus philippii*	Peters	1866
Subantarctic fur seal	*Arctocephalus tropicalis*	Gray	1872
Antarctic fur seal	*Arctocephalus gazella*	Peters	1875
Guadalupe fur seal	*Arctocephalus townsendi*	Merriam	1897
Galápagos fur seal	*Arctocephalus galapagoensis*	Heller	1904
Hawaiian monk seal	*Monachus schauinslandi*	Matschie	1905
Galápagos sea lion	*Zalophus wollebaeki*	Sivertsen	1953

curve, Paxton (1998) found that as many as 47 large open-water marine animals still await description, with an average interval between descriptions of approximately 5.3 years. New data later caused him to raise this figure to 51 (Paxton 2001), but more recent study predicts a lower number (Paxton personal communication 2006). Raynal (2001) applied the same technique to the cetacean description record, concluding that 15 cetacean species might await description. Solow and Smith (2005) also examined this issue and concluded that approximately 10 large marine animal species await discovery, although they also found good statistical support for the possible presence of as many as 16 undiscovered species.

A legitimate question to ask is how many more species of pinniped await discovery and/or description. Here, we address this issue in two ways. Firstly, we estimate the number of pinniped species awaiting description by making extrapolations with the aid of various curves, statistically fitted to the pinniped cumulative description record. Secondly, we review the cryptozoological literature with a view to examining the putative characteristics of potentially undescribed pinniped species.

Modelling trends in the description record

In the past, large-bodied marine species were discovered and described at a far higher rate than in the current era. Zoologists and ecologists have been using data on the enrichment patterns of species inventories in an effort to try to estimate, via extrapolation, the numbers of species (within given parameters) left to be found. This approach was pioneered in the early 1980s for studying research and publication trends in zoology (Simon 1983). Paxton (1998) utilised a non-linear regression (rectangular hyperbola fitted) curve in the prediction of the numbers of yet-to-be-described marine species possessing a length of greater than or equal to 2 m along a major axis. Raynal (2001) similarly employed non-linear regression in an effort to model the cetacean description record. Solow and Smith (2005) employed a variant explicit statistical model for the discovery process, whereby the discovery record was fitted by the method of maximum likelihood.

Description has been largely used in preference to discovery as, even though many years can elapse between the two, description marks the point at which a new species is officially recognised by zoology. This greatly reduces the ambiguity associated with its zoological standing (Paxton 1998).

Non-linear regression

As was mentioned previously, Paxton (1998) and Raynal (2001) fitted the particular species description records that they studied using non-linear regression. This was achieved using the Michaelis–Menten function, which is most famous for its application in the modelling of enzyme kinetics (Michaelis and Menten 1913).

$$S_{(n)} = \frac{S_{(\max)} n}{B + n}. \tag{1}$$

Where n is equal to the number of years that have elapsed since the origin year of interest, $S_{(n)}$ represents the difference between the numbers of species known in the origin year and the numbers of species known in the present year. $S_{(\max)}$ and B are regression constants calculated through the method of lesser squares. When modelling the description record for pinnipeds, values of 50.464 and 89.637 were calculated for the constants $S_{(\max)}$ and B respectively.

It is evident from the graph (Figure 1) that the curve has yet to reach an asymptote. Based on this, it is possible to extrapolate the numbers of pinniped species awaiting description by simply subtracting the current number of known pinniped species (36) from the calculated value of the constant $S_{(\max)}$ (rounded up to 51). This gives us 15 potentially undescribed species remaining. A problem in using this approach to fit the graph is that, despite the fact that the curve approximates the initial description record with reasonable accuracy, it declines sharply after 1800 to the point where the description record is significantly out of phase with the predicted trend. In all likelihood, therefore, the extrapolated value of 15 remaining undescribed pinnipeds represents a sizable over-estimation of the true numbers remaining to be described.

In order to get a better idea of the potential range of predicted values, it will be necessary to fit the description record using another method for comparison.

Logistic regression

Logistic regression, which has been employed extensively in ecology (Trexler and Travis 1993), is used in order to predict the probability of a given outcome by fitting the data to a logistic curve. In order to fit the pinniped description record using such a curve the following function was employed:

$$S_{(n)} = \frac{S_{(0)}}{1 + \mathrm{e}^{((X_{\mathrm{mid}} - n)/\phi)}}. \tag{2}$$

Three parameters, ϕ, X_{mid} and $S_{(0)}$, which is an asymptotic value (as $n \rightarrow \infty$), had to be estimated. These values were determined at 34.080, 56.800 and 35.260, respectively.

This curve better approximates the description record for pinnipeds, especially in terms of modelling the more recent description record (Figure 2). However, the logistic

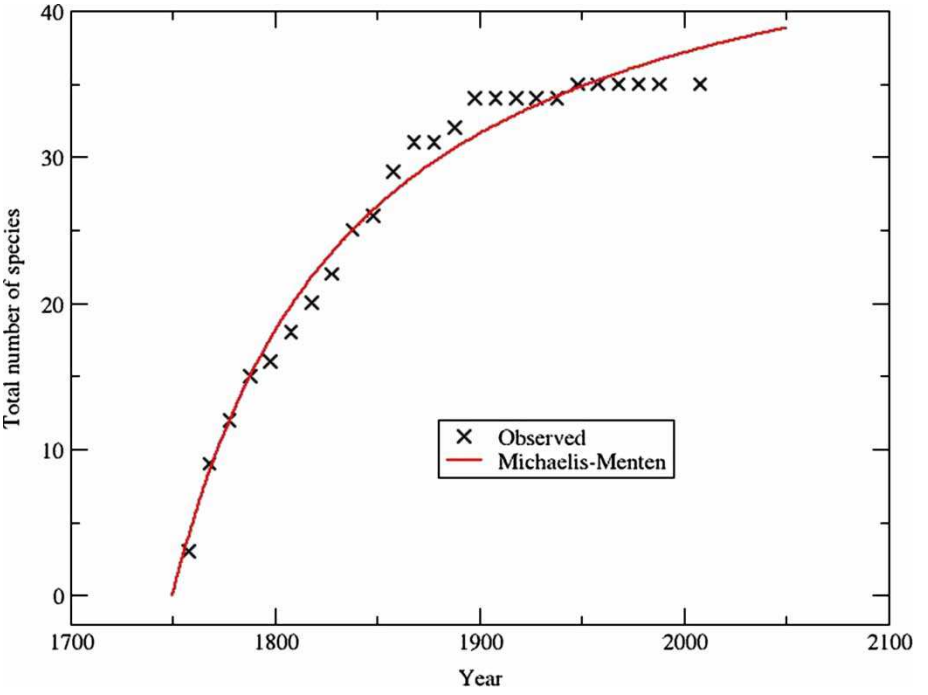

Figure 1. Curve for the description record of the pinnipeds fitted using Equation (1).

function, unlike the Michaelis–Menten function, does not allow for accurate modelling of the initial description record. Based on the logistic function, 0 species of pinniped remain to be described. As neither approach completely accurately approximates the pinniped description record, we conservatively estimate an upper and lower bound for the predicted number of undescribed pinniped species to be 15 and 0, respectively.

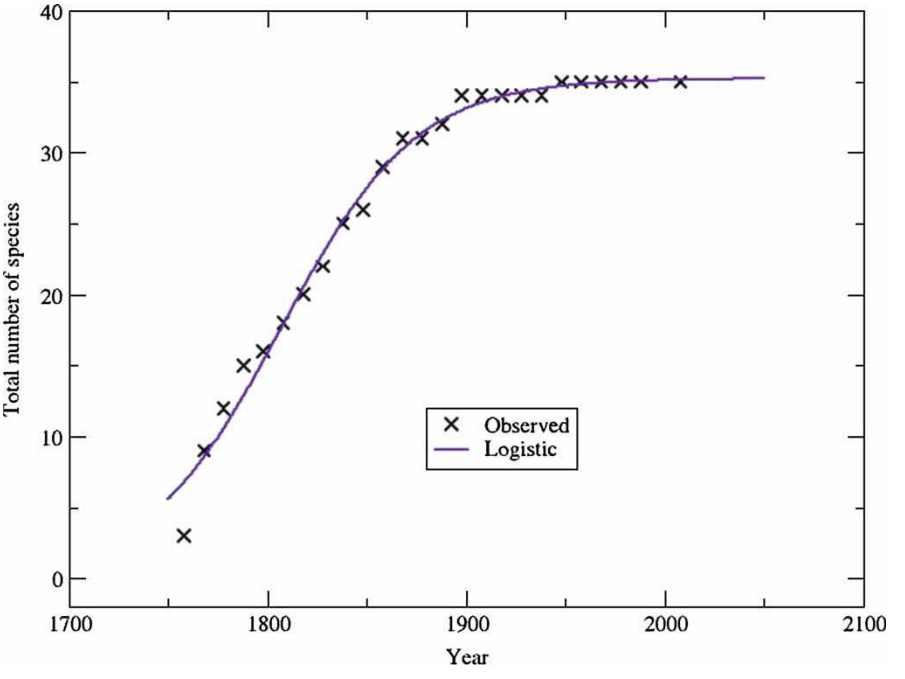

Figure 2. Curve for the description record of the pinnipeds fitted using Equation (2).

The cryptozoological record

Cryptozoology comprises a set of targeted research methodologies, the combined objective of which is to elucidate the identities of organisms known only theoretically, anecdotally, ethnozoologically or through other non-autoptic evidences (Heuvelmans 1982; Arment 2004). The naïve view that cryptozoological research methods are only practised by people on the fringes of the scientific community, and furthermore consistently result in failure, is falsified by the fact that new species continue to be discovered following the investigation of eye-witness reports, deductive inference and/or ethnozoological knowledge systems. A partial list of vertebrate species that have been discovered in this way would include the Okapi *Okapia johnstoni*; Saola *Pseudoryx nghetinhensis*; Leaf deer *Muntiacus putaoensis*; Odedi *Cettia haddeni*; Kipunji *Rungwecebus kipunji* and Giant peccary *Pecari maximus* (Sclater 1901; Dung et al. 1993; Rabinowitz et al. 1999; Jones et al. 2005; LeCroy and Barker 2006; van Roosmalen et al. 2007). An ethnoknown Asiatic cryptid bovid, the Kting Voar, is currently the object of much zoological controversy, and has even been christened with the binomial *Pseudonovibos spiralis* (Peter and Feiler 1994a, 1994b; MacDonald and Yang 1997). Another species worth mentioning in this context is the Madagascan hawk moth *Xanthopan morgani praedicta*, which was predicted to exist by Darwin (1862) on the basis that a moth possessing a proboscis of at least 25 cm would be required in order that the comet orchid *Angraecum sesquipedale* be pollinated (Darwin 1862). The moth was finally described in 1903, 41 years after Darwin had theorised its existence (Rothschild and Jordan 1903).

Cryptozoologists have long speculated on the possible existence of undiscovered species of pinniped, and cryptozoological research methods have been used to investigate reports of pinnipeds or pinniped-like marine mammals. Richards (1994) investigated cases of a supposed 'upland seal' reported from the Antipodes and Macquarie islands: suggested by some authors to be a distinct, recently extinct species (Falla 1948; Csordas and Ingham 1965; Shaughnessy and Fletcher 1987), 'upland seals' were argued by Richards (1994) to be young individuals of the New Zealand fur seal *Arctocephalus forsteri*. Several authors have evaluated eyewitness reports of alleged 'sea cows' reported from Saint Helena (Lydekker 1899; Mortensen 1934; Fraser 1935; Shuker 2003), and based on descriptions have concluded that the animals most likely represented known pinnipeds, with the Cape Sea lion *A. antarcticus* and Southern elephant seal *Mirounga leonina* being offered as the most likely identifications. Boyd and Stanfield (1998) used interview data to assess the possible survival of the Caribbean monk seal *Monachus tropicalis* beyond its probable extinction date of 1952. Sporadic sightings beyond this date suggest that the species might survive in the region: the data collected by Boyd and Stanfield (1998) indicated that local fishermen had witnessed the species 1–2 years prior to 1997.

Several other crypto-pinnipeds have been much discussed in the cryptozoological literature, but have never been adequately assessed in the peer-reviewed literature. We recognise that this is partly due to the reluctance of many technical zoologists to take these proposed creatures seriously. It should be noted that peer-reviewed papers on cryptozoology were published in the now defunct journal *Cryptozoology*, and have appeared elsewhere in the mainstream literature (Scott and Rines 1975; Raynal and Sylvestre 1991; Paxton et al. 2005; Paxton and Holland 2005). Nevertheless, the exclusion of many cryptids from the formal literature has prevented technical appraisal. In turn, this has helped perpetuate a cycle in which these alleged creatures remain predominantly in the 'grey literature' and are never really objectively assessed. We feel that it is time to redress this, and here we present an overview of the putative cryptid pinnipeds considered to be current and legitimate research targets by cryptozoologists (Heuvelmans 1986; Shuker 1998).

Heuvelmans's long-necked sea-serpent

Heuvelmans (1968) postulated the existence of a large to gigantic (5–18 m long) long-necked pinniped in order to account for observations of marine cryptids in which long necks and other plesiosaur-like traits had been reported. He coined the scientific name *Megalotaria longicollis* (meaning 'big sea lion with the long neck') for this cryptid. Oudemans (1892) had earlier postulated the existence of a similar creature, and had proposed for it the name *Megophias megophias* (meaning 'big snake'). In part because *Megophias* was inferred to possess a long tail, Oudemans (1892) proposed that it belonged to a group (termed the Longicaudata), which had diverged from all other pinnipeds (grouped together as the Brevicaudata) early on in the evolutionary history of the group.

Of incidental interest is that Heuvelmans (1968) argued that the name *Megophias* should be abandoned as, in his view, it was based on a confused combination of different creatures, and he regarded the recognition of *Megalotaria* as novel to his work. *M. longicollis* was only one of several new binomials that Heuvelmans published in his cryptozoological writings: while apparently aware of the rules of the International Commission on Zoological Nomenclature (ICZN) governing the assignment of binomial nomenclature, he suggested that scientific names in cryptozoology should be treated in the same vein as the parataxonomic names used for trace fossils (Heuvelmans 1982). Parataxonomic nomenclature is currently considered heterodox (as it was when

Heuvelmans penned his defence of generating binomials for cryptids). Interestingly, however, it has been suggested that a reasonable, but not necessarily rigorous, interpretation of the text of the ICZN regarding the need for physical voucher specimens does not preclude the granting of binomials in the absence of such specimens, neither do cryptids strictly qualify as 'hypothetical concepts' (Dubois and Nemésio 2007). As Dubois and Nemésio (2007) observed, cryptid binomials, such as those proposed by Heuvelmans, must be considered as currently having ambiguous taxonomic standing.

Heuvelmans (1968) based his conclusions about *Megalotaria* on the fact that many of the 48 sightings that he deemed 'certain' seemed to involve animals exhibiting distinctly mammalian, and specifically pinniped, traits, such as the presence of hind flippers, fur, and a dog-like head shape complete with whiskers. Heuvelmans theorised that the long-necked sea-serpent represented a morphologically derived otariid, exhibiting marine parturition and a largely aquatic lifestyle, although he did suggest that it was capable of terrestrial locomotion, based on the testimony of a small number of witnesses who claimed to have encountered it in this context (Heuvelmans 1968). Essentially the long-necked sea serpent was to be the product of evolutionary relay, which would have resulted from an otariid lineage convergently evolving into a niche similar to that left vacant by the extinction of elasmosaurid plesiosaurs in the Late Cretaceous (Heuvelmans 1968; Woodley 2008). Despite this convergence, however, Heuvelmans's long-necked sea-serpent seems to possess some unique and distinctly non-reptilian characteristics, including a pair of nasal snorkels which, it was proposed, might be used without needing to fully surface, and a neck that could be held in a vertical orientation whilst spy hopping (Heuvelmans 1968; Naish 2001). Another interesting trait with which Heuvelmans imbued this putative pinniped was euryhalinity, as he believed it to be additionally responsible for a number of fresh water cryptid reports, a thesis that has been further developed by subsequent authors (Costello 1974; Coleman and Huyghe 2003; Cornes 2007; Champagne 2007).

Taken at face value, the better eyewitness accounts of long-necked marine cryptids do sound like descriptions of giant, long-necked pinnipeds, and given that relatively long-necked pinnipeds existed in the past (de Muizon 1981), and that pinnipeds have achieved gigantic sizes (6.2 m and >3 ton in *M. leonina*: Ling and Bryden 1992), their existence is not entirely implausible. However, given that phocids are more strongly adapted for pelagic life than are otariids, and have achieved larger body sizes, Heuvelmans's suggestion that his hypothetical giant pinniped might be an otariid can be criticised given that otariids are the most terrestrial of pinnipeds. Heuvelmans (1968) seems to have arrived at the otariid conclusion based on a 1913 account in which Oscar Davies and W. Harris described how a Tasmanian animal seen on a beach 'travelled by bounding – that is, by arching its

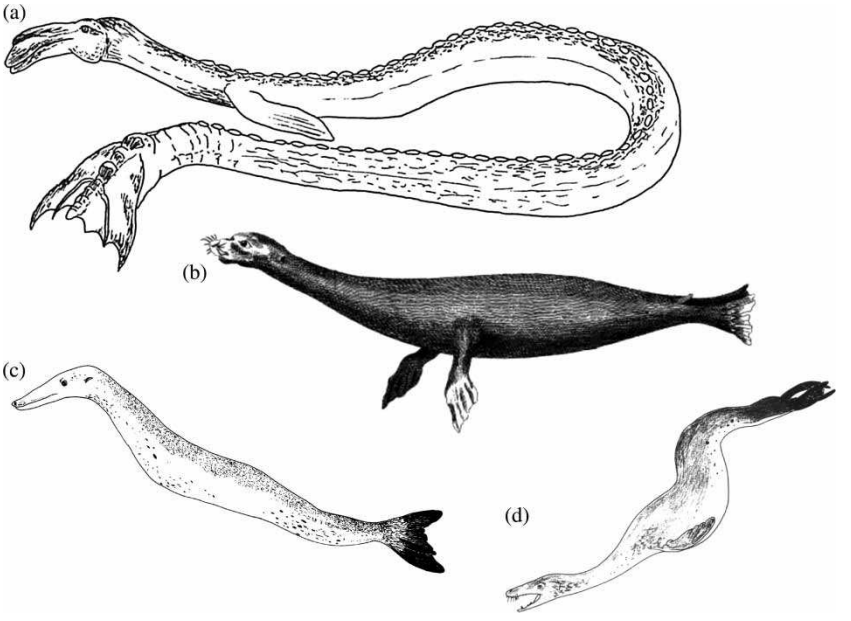

Figure 3. (a) Reconstruction of *Cadborosaurus willsi* after LeBlond and Bousfield (1995); (b) The 'long necked seal' as depicted in Parsons (1751); (c) Reconstruction of *Tizheruk* after Mackal (1983). (d) Reconstruction of the swan-necked seal *Acrophoca longirostris* after de Muizon (1981).

back and gathering up its body so that the footprints of the forefeet were level with those of the hind feet' (Heuvelmans 1968, p. 391).

Evidently little known is that an extant pinniped termed the 'long necked seal or sea calf' (Figure 3(b)), was described by Parsons (1751). Reporting the observations of a Dr Grew on an animal observed 'in diverse countries' it was described thus:

> '[M]uch slenderer than either of the former [two other pinnipeds were described earlier in the manuscript]; but that, wherein he principally differs, is the length of his neck; for from his nose-end to his fore-feet, and from thence to his tail, are the same measure; as also in that, instead of his fore-feet, he hath rather fins; not having any claws thereon, as have the other kinds. The head and neck of this species are exactly like those of an otter. One of those, which is also now in our musaeum [sic], taken notice of by the same author, has an head shaped like that of a tortoise; less in proportion than that of every other species, with a narrowness of stricture round the neck: the fore-feet of these are five-finger'd, with nails, like the common seal. Their size, as to the utmost growth of an adult, is also very different. That before described, was 7 feet and an half in length; and, being very young, had scarce any teeth at all' (Parsons 1751, p. 111).

It is not possible to determine whether this 'long necked seal' has anything to do with Heuvelmans's hypothetical animal of similar name: it is tempting to assume that it was a confused description of a sea lion but, given the 2.3 m length of a specimen described by Parsons as being juvenile, it sounds like an unusual animal to say the least. However, Parsons also mentioned a specimen, which 'is but 3 feet long, is very thick in proportion, and has a well-grown set of teeth' (Parsons 1751, p. 112). The tantalising possibility remains that the larger specimen would have been significant in zoological terms, but given that we lack data on the provenance and fate of the specimens that were described, any further comments would be entirely speculative.

Heuvelmans's merhorse

Another pinniped, this time of uncertain affinity, was invoked by Heuvelmans in order to account for the 'merhorse', a marine cryptid with a pedigree stretching back into antiquity, so named because of the horse-like head, mane and long neck that is common to sightings (of which 37 were considered 'certain' by Heuvelmans). As discussed below, we include *Cadborosaurus willsi* within our discussion here following Heuvelmans's (1968) contention that it and the merhorse and, for the most part, one and the same. According to Heuvelmans (1968), the merhorse (*Halshippus olaimagni* [Heuvelmans incorrectly transcribed this name as *Halshippus olai-magni*] meaning 'waterhorse of Olas Magnus') exhibited a greater size range than the long-necked sea-serpent (4.5–30 m) and was believed to be adapted to an abyssal niche. Sanderson (in Heuvelmans 1968) speculated that its mane might have functioned as an auxiliary respiratory organ, and that each 'hair' might have contained respiratory pigments functioning in direct gas exchange with water (a trait seen elsewhere in the tropical African astylosternid frog *Trichobatrachus robustus*). However, a far more plausible explanation for these manes might be that they are simply the product of sexual selection, as there appear to be tentative indications of dimorphism in the observational data for this cryptid (Coleman and Huyghe 2003; Woodley 2008).

This cryptid has been the subject of a not inconsiderable degree of controversy. Bousfield and LeBlond (1995) reported the discovery of photographs, taken in 1937 on a flensing platform at Naden Harbour, Queen Charlotte Islands, Canada, that show an unusual long-bodied carcass, reportedly recovered from the stomach of a sperm whale. The carcass appears to include a superficially camel-like head and an apparently symmetrical caudal fluke-like structure with a central series of knobs that appear to correspond to vertebrae. The 'body' is elongate and serpentine and there appear to be pectoral flippers. While parts of the carcass were apparently retained and forwarded to the Pacific Biological Station at Nanaimo and/or the Royal British Columbia Museum, Victoria, no material remains today and the specimen is regarded as lost to science (Bousfield and LeBlond 1995).

By combining observations on this carcass with eyewitness reports, Bousfield and LeBlond (1995) formally described it as a new species, *C. willsi* (Figure 3(a)), and Supplement 1 of the new journal *Amphipacifica* was devoted to their description of this taxon. One of the Naden Harbour photographs was selected as the holotype of the ostensible new species. Bousfield and LeBlond proposed that *Cadborosaurus* might represent a surviving plesiosaur (in Bousfield and LeBlond (1995), p. 8, it is classified as 'Class Reptilia, Subclass Euryapsida?, Order Plesiosauria?') and made speculations about its lifestyle, style of locomotion, feeding behaviour, and even its breeding behaviour and physiology (see also LeBlond and Sibert 1973; Bousfield and LeBlond 1992; Dash 1993; Park 1993). The naming of this new species attracted criticism (Staude and Lambert 1995; Bauer and Russell 1996) and the identification of the carcass as that of an extant sauropterygian was unsupported and completely speculative. The identification of the Naden Harbour carcass remains uncertain: it appears to represent that of a long-bodied vertebrate with a superficially horse-like head, pectoral fins and a fluked tail. The photos are undoubtedly tantalising, but in the absence of physical remains it is unfortunately not possible to come to any firm conclusions about the identity of the Naden Harbour carcass.

As was mentioned previously, Heuvelmans (1968) considered a number of '*Cadborosaurus*' sightings to be of a merhorse and therefore of a new pinniped species. Although an identification of this cryptid as an aquatic mammal is more compatible with what is known of this cryptid (maximum flexibility in the vertical plane, hair, pinnae, fused hind flippers, cold water tolerance, etc.), if the merhorse is a pinniped, it is one exhibiting exotic, bizarre characteristics such as an unusual degree of flexibility and an unprecedentedly high fineness ratio (Bousfield and LeBlond 1995).

Tizheruk

Mackal (1983) reported the possible existence of an Arctic counterpart to the Antarctic leopard seal *Hydrurga leptonyx* in the form of a cryptid known as *Tizheruk* amongst the natives of King Island, Alaska. This cryptid (or one very much like it) is also known as *Palraiyuk* on the more southerly island of Nunivak. Described as possessing a large, snake-like head atop a 2.1–2.4 m neck, it is also said to possess a bifid fluke-like structure located at the tail tip (Figure 3(c)). Mackal (1983) speculated that its elongated neck, coupled with the possible loss of forelimbs, have combined to give this putative pinniped a superficially reptilian appearance. The natives claimed that it is highly aggressive and that it could be attracted by the vibrations generated by tapping on the side of a boat which, as Mackal (1983) observed, is also a means of attracting leopard seals. Also of interest is the fact that, of all the extant pinnipeds, leopard seals are the most 'reptilian' in appearance.

Nearly all of the information concerning this cryptid, which figures prominently in Inuit lore from the region, comes from the ethnozoological work of Dr John White, who spent much time with the Inuit attempting to build a description of the animal. White subsequently shared much of what he found with Mackal (1983). Swords (1991) reviewed Pacific Northwest traditions of the *Wasgo* or *Sisiutl*, a long-tailed swimming animal, more powerful than a killer whale and with a long-snouted, horned head. Swords (1991) regarded the *Wasgo* or *Sisiutl* as synonymous with the *Palraiyuk* and also noted various other regional names used for this totemic beast. While it has been implied that these mythical creatures are the same thing as *Tizheruk* (Swords 1991; Cornes 2007), attributes such as horns, a long, spear-like tongue and the presence of six legs in the *Palraiyuk* pose problems for a zoological interpretation.

Discussion and conclusions

Based on two approaches to fitting the pinniped cumulative species description record, hypothetical upper and lower ranges for the number of currently undescribed pinniped species have been suggested. This does not take into account the fact that each extreme of this range may not be equally weighted probability-wise. The number 15, which is the number of undescribed pinnipeds predicted using a Michaelis–Menten function, is probably a significant over-estimate of the true number likely to exist. Raynal (2001) predicted the existence of 15 undescribed cetacean species by applying the same function to the cetacean description record, and it is evident from his data that the projected curve compliments the much larger cetacean description record far better than the pinniped description record.

Logistic regression seems to fit the pinniped description record much more precisely than does regression based on the Michaelis–Menten function. More importantly, it seems to better approximate the more recent description record, although it fails to approximate the early description record as well as the Michaelis–Menten function. In addition, it may not compensate adequately for the post-1900 'plateaus' evident from the graphs. An implication of this is that the number of pinnipeds awaiting description may well be greater than 0, but is not likely to be anywhere nearly as high as 15. It is interesting to note that the cryptozoological record for cryptid pinnipeds indicates the existence of only three undescribed but ethnoknown species. This number, therefore, seems to be a reasonable estimate of the likely numbers left to be described given the above observations.

It is additionally necessary to point out that a variety of assumptions have been made in the selection of these models. The description record for pinnipeds has been chosen in preference to the discovery record, following the protocol of Paxton (1998). Similarly, only taxa currently recognised are included in the analysis. As mentioned previously, a number of novel pinniped bimonials were coined in the twentieth century; inclusion of these would radically alter the properties of the description record, in addition to which the numbers of pinniped species predicted through regression analysis would in all likelihood be radically altered also. We defend the use of Paxton's (1998) inclusion criteria on the basis that, as has already been mentioned, description equates with formal recognition, thus providing a taxonomic baseline for estimates of species numbers. Pre-1758 vernacular descriptors are ambiguous: the same species of pinniped could have been known via several different names prior to 1758. This factor would therefore artificially inflate the discovery record. Similarly, the inclusion of currently invalidated post-1758 taxa would have similarly made the estimates non-conservative. We believe, that, when dealing with a subject as speculative as cryptozoology, it is better to adopt a conservative stance when assessing the enrichment of species inventories.

A significant question to ask is: how plausible are the identity theories behind these cryptids? Heuvelmans (1968) postulated that the long-necked sea-serpent had managed to occupy an approximation of the niche left vacant by elasmosaurids. Palaeontological evidence shows that some fossil pinnipeds approached plesiosaurs in morphology more than do extant species: in the so-called swan-necked seal *Acrophoca longirostris* from the Upper Miocene Pisco Formation of Peru (Figure 3(d)), the neck comprised approximately 21% of its total vertebral column length (de Muizon 1981), this is compared to 17–19% in the majority of extant phocids (King 1983). Additional *Acrophoca* species that are yet to be described appear to have possessed even longer necks (Walsh and Naish 2002). It should be noted that the hypothetical *Megalotaria* has presumably lengthened its neck by increasing the length of its vertebrae, and not by the addition of new cervical elements. As is well known, mammals appear to be constrained to a neck consisting of seven vertebrae, apparently because changes in *Hox* gene expression are associated with neural problems and with an increased susceptibility to cancer (Galis 1999). The exceptions (some sloths and sirenians) might circumvent the constraint by virtue of their low metabolic rates and corresponding low susceptibility to cancer (Galis 1999).

The hypothesis that some small number of pinniped species succeeded in occupying plesiosaur niches and, in so doing, became exclusively aquatic is not entirely implausible based on what has recently been learned of pinniped evolution. Conversely however, the immense size of some of these cryptid pinnipeds compared to their extant counterparts does cast doubt on their proposed existence. Given that pinnipeds are generally noisy and obvious due to their habit of breeding, basking and moulting terrestrially, the hypothesis that gigantic, globally distributed species might have escaped regular human attention is unlikely. Heuvelmans (1968, 1982) did, however, consider relative rarity to be a primary reason why the various hypothetical creatures of interest to cryptozoology have so successfully evaded formal identification. It has also been shown theoretically that a viable cryptid population could, in many cases, still be sufficiently rare so as to effectively evade detection for long periods of time (Guynn et al. 1985; Brussard 1986). The possibility that these pinnipeds could be fully divorced from land, as proposed by Heuvelmans (1968) and Mackal (1983), is also appealing but, following a hypothesis proposed by Trillmich and Trillmich (1984), we note that the terrestrial breeding and moulting of pinnipeds may be a constraint that prevents them from adapting fully to pelagic life.

Ultimately, only with the passage of time will the question of whether there remain undescribed pinniped species be resolved, irrespective of how intriguing the evidence.

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